Effect of High-Pressure-Freezing on Textural and Structural Quality of Frozen Agar Gel

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To determine the effect of high-pressure-freezing on quality, agar gel was frozen at 100 – 700 MPa at ca. -20°C . After reduction to atmospheric pressure, gel was thawed. Texture and structure of gel frozen at 200 – 400 MPa improved compared to the gel frozen at 0.1, 100, 600 and 700 MPa, but differed from the original gel. Gel was also thawed at high pressure, then pressure was reduced. Texture of gel frozen at 200 – 400 MPa was the same as the original gel. This suggested that phase transitions (ice VI $\rightarrow$ ice V $\rightarrow$ ice III $\rightarrow$ liquid $\rightarrow$ ice I) occurred during reduction of pressure at -20°C . Thus high-pressure-freezing-thawing at 200 – 400 MPa was effective on the improvement in quality of frozen gel. [agar gel, high pressure, freezing, thawing, texture]

1. Introduction

Agar gel frozen at atmospheric pressure collapses and does not recover its gel phase when thawed. With foods of high water content (i.e. agar gel, tofu, konjac, steamed egg custard, vegetables, or fruits), damage to structures through freezing is extensive and the texture after thawing becomes unacceptable. In previous studies [1][2] it was found that during phase transition from water to ices, ice I expands in volume, but high pressure ices (ice II – ice IX) do not. If the high density property of high pressure ices is applied to frozen agar gel, damage of gel may be prevented. The objective of this study was to research the effect of high pressure on the improvement in quality of agar gel. Therefore, texture and structure of agar gel frozen at 100 MPa (ice I), 200 MPa (liquid phase), 340 MPa (ice III), 400, 500, 600 MPa (ice V) or 700 MPa (ice VI) at ca. -20°C were compared with the non-frozen original gel, pressurized gel or gel frozen in freezers (-20°C , -30°C or -80°C) at atmospheric pressure (0.1 MPa).

2. Materials & Methods

Seven pieces (15 mm in diameter and 5 mm high) of 1.5% (W/W) agar gel {concentration of sucrose: 0%, 5%, 10% or 20% (W/W)} were vacuum packed in heat-sealed polyethylene bags. Four packs of samples with various concentrations of sucrose were placed into propylene glycol (pressure medium) in a pressure vessel (6 cm ϕ $\times$ 20 cm) previously kept at ca. -20°C by circulation-type cooler, and immediately pressurized for 45 min at 100 – 700 MPa using a Dr. Chef high pressure food processor (Kobe Steel Ltd.) [3].

After reduction of pressure, agar gel was stored for 1 day at -30°C then thawed at 20°C in a low temperature incubator. This gel was compared with untreated (original) samples, samples pressurized at room temperature (non-frozen) or frozen on prechilled aluminum plates in freezers (-20°C , -30°C or -80°C) at atmospheric pressure (0.1 MPa).

To determine phase transition of ices during reduction of pressure, agar gel was thawed at high pressure. After high-

pressure-freezing for 45 min, the pressure vessel was heated by a circulation-type-heater (60°C) for about 70 min at the same pressure as high-pressure-freezing. When temperature of the pressure medium reached 20°C , pressure was reduced.

After the amount of drip (syneresis) was measured, texture was measured by a creepmeter (Rheoner, RE-33005, Yamaden Ltd.) [4]. The structure of gel was observed with a cryo-scanning electron microscope (S-4500, Hitachi Ltd.) [5]. The ice pore size of frozen agar gel was measured using software for image analysis (Mac-scope, Mitani Ltd.).

Fig. 1. Phase diagram of freezing and thawing methods.

○ pressurization, ◻ storage, — high-pressure-freezing, — high-pressure-thawing, - - - atmospheric pressure-thawing

3. Results & Discussion

Texture and structure of agar gel high-pressure-frozen-then-thawed at atmospheric pressure

Pressurization at room temperature did not affect visual appearance, texture and structure of agar gel. However, in agar gel frozen at 0.1, 100, 600 and 700 MPa appearance, texture (force distance curves) and structure differed greatly from the

original gel due to syneresis and a volumetric shrinkage of gel (Figs. 2, 4 - 7) The pore size of gel without sucrose was large and the gel network contracted slightly. Therefore, final rupture stress and strain increased (Fig. 2); and, with an increase of sucrose, appearance, texture and structure of gel improved slightly (Figs. 4 - 6).

On the other hand, appearance of agar gel without sucrose, frozen at 200 – 400 MPa, was the same as the original gel (Fig. 5). Although stress decreased and strain increased, they were more similar to the original gel than gel frozen at 0.1, 100, 600 and 700 MPa. The ice crystals in agar gel frozen at 200 – 400 MPa were smaller than in agar gel frozen at 0.1, 100, 600 and

700 MPa. When agar gel was frozen at 200 – 400 MPa, the quality of frozen gel improved compared to gel frozen at atmospheric pressure, but differed from the original gel. These results suggested that ice I might be formed during reduction of pressure or during storage of gel in a freezer. Thus, the quality of agar gel became worse due to volume expansion by the formation of ice I.

Texture and structure of agar gel high-pressure-frozen-then-thawed at high pressure

To determine phase transition of ices during reduction of pressure, high-pressure-frozen agar gel was thawed at high pressure (the same pressure as high-pressure-freezing) then

Fig. 2. Force-distance curves of agar gel (0% sucrose) high-pressure-frozen then-thawed at atmospheric pressure.

Fig. 3. Force-distance curves of agar gel (0% sucrose) high-pressure-frozen then-thawed at high pressure.

Fig. 4. Effect of high-pressure-freezing on textural quality of frozen agar gel.

□ 0%, □ 5%, ▨ 10%, ■ 20% Sucrose

Fig. 5. Visual appearance of frozen-thawed agar gel.

Fig. 6. Cryo-scanning electron micrographs of agar gel high-pressure-frozen-then thawed at atmospheric pressure.

Fig. 7. Cryo-scanning electron micrographs of agar gel frozen in freezers (-20°C, -30°C, -80°C) then thawed at atmospheric pressure.

pressure was reduced. Texture of agar gel frozen at 200 – 400 MPa was the same as the original agar gel (Fig. 3). This suggested that phase transitions (ice VI $\rightarrow$ ice V $\rightarrow$ ice III $\rightarrow$ liquid $\rightarrow$ ice I) occurred during reduction of pressure at -20°C, or during storage in a freezer. Thus high-pressure-freezing-thawing at 200 – 400 MPa effectively improved the quality of frozen agar gel.

References

- [1] N. H. Fletcher, *The Chemical Physics of Ice*, Cambridge University Press, London, 1970.
- [2] P. V. Hobbs, *Ice Physics*, Oxford Univ. Press, London, 1974.
- [3] N. Kato-Hyakumoto, A. Teramoto, and M. Fuchigami, *J. Food Sci.*, **62**, 359 (1997).
- [4] M. Fuchigami and A. Teramoto, *J. Food Sci.*, **62**, 828 (1997).
- [5] M. Fuchigami, N. Hyakumoto, and K. Miyazaki, *J. Food Sci.*, **60**, 137 (1995).